NOTES ON ELECTRICITY.

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I.—THE DYNAMO IN ELECTRO-THERAPEUTICS.

IT has been suggested by several in the past few years that the dynamo would in the near future be used for medical purposes, as it is a much cheapear method of generating electricity than by galvanic cells. Most doctors have supposed that a dynamo would have to be constructed especially for medical use. Although that could be done, as all that would be necessary in ordering one would be to give the dynamo manufacturer the E. M. F. and capacity—as example, E. M. F., 70 volts; capacity $\frac{1}{4}$ of an ampère, that would make a small dynamo, but would be large enough for medical purposes.

I do not think dynamos constructed especially for medical purposes will come into general use, as there are several obstacles in the way.

First it is necessary to have a very steady power, and that is not generally available without too much expense, and if we have a steady power it requires a great deal of skill to keep it well adjusted; if the power is not steady the current will be very wavy, which makes it so harsh and painful that it is not adapted for medical use. Secondly, it requires a degree of mechanical skill to keep a dynamo in order that is not generally possessed by medical men.

The figures that I gave above as being all that are required in ordering a dynamo adapted for medical purposes, I gave on the authority of an electrician representing the Edison company.

There is a dynamo used in the arts that *is* adapted for medical use, and it is coming into use so fast that it will soon be available in the cities and all of the towns of any considerable size, viz.: the dynamo used for incandescent lighting.

I have been experimenting with, and using in my practice since Oct. 5, 1885, the current used for Edison incandescent lights, produced by two dynamos that are running with an E. M. F. of 110 volts connected in surface.

The current at my office where I take it off has an E. M. F. of 100 volts nearly.

I extend the wires from the ceiling to about the level of the table, where they terminate in metal posts that have holes bored in them to make connections with the rheophores or conducting wires. I use for conducting wires those used for connecting the lights in the Edison system, composed of twelve strands of copper wire covered first with rubber, then linen, and last of all silk.

I find these far superior to the ordinary conducting wires furnished with batteries.

I connect one wire with the rheostat,[1] one that I have constructed for the purpose; then I connect the rheostat with an exact galvanometer graduated in milliampères, made by John A. Barrett of New York.

I then connect the galvanometer with one of the electrodes and the other conducting wire with the other electrode; then every thing is ready for work.

Although the dynamo current is an alternating one when produced, it is turned one way by means of a commutator in all dynamos used for incandescent lighting; it then has all the properties of a galvanic current; it will magnetize steel, heat wire, and produce electrolysis of water, or the solutions of the salts, and is practically a galvanic current.

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[1] I omitted the description of my rheostat because I am going to change its form in order to make it more convenient.

The current used for incandescent lighting is not dangerous to use unless the lights are in series.

It is necessary to use a resistance of from 10,000 to 100,000 ohms for every 100 volts of E. M. F.

The E. M. F. can be ascertained, if the lights are arranged in surface, by simply looking at the top of the lamp.

This dynamo current is well adapted for medical purposes, as its E. M. F. 100 volts is not much higher than some office batteries, and although there are 160 ampères produced by the dynamos, this makes no difference, as with 100 volts E. M. F., and say 100,000 ohms resistance, we can get only one milliampère, whether the dynamos have a capacity of 160 or $\frac{1}{10}$ of an ampère.

There is a theoretical objection to the dynamo current, and that is, it is a little wavy. Although the one used for incandescent lighting gives a comparatively steady current, it is impossible to construct a dynamo that will give as constant a current strength as can be produced by chemical action.

In calculating on the constancy of an electric current, one must take into consideration not only the E. M. F. of the machine, but also the constancy of the resistance.

Now as the body offers a very inconstant resistance, frequently varying as much as one fourth or one third in three or four minutes by the soaking of the skin and the increased blood supply to the parts, it follows that with the most constant battery we have a very inconstant current strength; that can be easily proved by an exact galvanometer.

Now suppose we take a battery and pass a current through the body, which has, say 3,000 ohms resistance; in three minutes it becomes reduced to, say 2,000 ohms, which increases the current strength one third in three minutes. Now take the powerful dynamo current and interpose a constant resistance of say 100,000 ohms, then add the body with its 3,000 ohms, and we have 103,000 ohms in the circuit.

If the resistance of the body is reduced to 2,000 ohms in three minutes, we have 102,000 ohms resistance in the circuit; that is, the current has increased only $\frac{1}{100}$ in three minutes. Thus we see with the most constant battery, unless we have a large number of cells and interpose a high resistance, it is impossible to get as constant a current strength as we get with a dynamo.

The dynamo current used in this way is smoother and less painful than a battery current of the same strength.

I have proved this repeatedly by giving to several persons a current of a definite strength—say five milliampères, and, with very few exceptions, they decided that the dynamo current was smoother and less painful.

I have found that the motor nerves and muscles react the same to the dynamo current as to the galvanic, viz.: K. C. C.; A. C. C.; A. O. C.; K. O. C., in the order named.

I find that the sensory nerves react in the same way as the motor nerves, viz.: K. C. S.; A. C. S.; A. O. S.; K. O. S.

The reaction of the gustatory nerves are interesting, but does not differ from that I have observed with the galvanic.

The positive pole, when placed on the tip of the tongue, gives a stronger metallic taste at the point of contact, also when placed on the side of the tongue, as near its báse as possible.

The negative pole, when placed on the tip of the tongue, produces more irritation of the tactile nerves, but the metallic taste is very faint at the point of contact, while at the base it is very strong; but when the negative pole is applied near the base of the tongue, the metallic taste is much weaker than when the positive is placed there. I think there is no doubt but that the metallic taste is stronger at the positive pole, and the foregoing observation can be explained by De Watteville's polar and peri-polar zone theory.

The effect on the optic apparatus is the same as with the galvanic current; that is, the conversion of electric stimulus into impressions of light.

The color of the flashes varies with different individuals.

The negative electrode produces more irritation of the tactile nerves, unless we use very strong currents; we get the heating effects, which are mostly at the positive pole, consequently there is more pain produced at the positive pole with very strong currents.

Electrolysis.

In producing electrolysis of blood, and also of a mixture of water, salt, and the white of an egg, I find that a light, frothy mass is produced at the negative pole, while at the positive a firm clot is produced.

The amount of gas given out at the negative pole tends to make it frothy, while the alkaline reaction probably tends to keep it in a semi-liquid state.

The heating effects at the positive pole, and probably the acid reaction, tend to make the clot firm and hard.

In producing electrolysis of beef, there is more liquefying action at the negative pole.

Electrotonus.

In carrying out my experiments on this subject, I have followed the method of De Watteville,[1] with such modifications as were necessary in using the dynamo current.

Experiment I.

I first pass the current from a secondary induction-coil through 20,000 ohms resistance. I place the negative electrode over the ulnar nerve, the positive on an indifferent point, and see at what distance of the secondary from the primary coil the induced current begins to produce contractions. I next connect the positive pole of the dynamo with the negative pole of the secondary induction-coil with the same resistance, that gives me five milliampères of dynamo electricity. I then place the combined negative electrode on the nerve; this produces very powerful contractions, and it produces moderate contractions with a much less powerful faradic current.

Experiment II.

I pass the faradic current through the same resistance with the positive pole on the nerve strong enough to produce moderate contractions. I then connect the negative pole of the faradic with the negative pole of the dynamo, with the same resistance; that gives me five milliampères of electricity.

The electrode that I place over the nerve combines the positive of the faradic and the negative of the dynamo current, and that produces no contractions.

I have not given the detail of any of the rest of my ex-

[1] De Watteville's "Medical Electricity," p. 111.

periments, because they were performed the same as if a galvanic battery with a rheostat had been used.

As the result of my experiments and observations, I find that the physiological and therapeutic effects of the dynamo currents are the same as those of the galvanic. What, then, are the advantages of the dynamo current? Economy and convenience.

In utilizing the dynamo current, all the appliances that are necessary are a rheostat and a galvanometer, and they are necessary accessories to an office battery, if one wishes to apply galvanism scientifically; so one can save the expense of the battery on the first outlay, and, besides, one saves the expense of repairs, which are considerable on a large office battery.

With the dynamo, eight or ten cents' worth of electricity is sufficient to treat patients, with average-strength currents, two hours a day for a year, and you have no battery to keep in repairs.

It is no more trouble to turn on the electricity for medical use than for purposes of lighting.

II.—HIGH OR LOW RESISTANCE BATTERIES FOR MEDICAL USES.

There seems to be a great deal of confusion on this subject which could be settled in a few minutes by considering the facts in the case.

Many writers on medical electricity claim that cells of high internal resistance give a smooth current especially adapted for medical uses; which they describe in a vague way as tension.

Bartholow says: "The best results are attained when the interior resistance of the battery is equal to the resistance in the exterior circuit."

He claims the best results are obtained from a modified Daniell cell, which has its internal resistance increased by papier-maché packing and a porcelain diaphragm, so that it equals the resistance offered by any part of the body.

Hence it is said to be smooth and unirritating when the

same number of elements of Stöhrer give rise to great irritation and burning.

In this fact we find the true explanation of the superiority in curative action of the large elements of a permanent battery as compared with the small elements of a portable battery.

He says the internal resistance should be 20 ohms or more per cell. Now the facts are these: 50 Daniell cells with 20 ohms resistance each, give when passed through—say 2,000 ohms external resistance, $\frac{52}{2000+1000} = \frac{1}{60}$ of an ampère. While 50 Stöhrer give $\frac{70}{2000+100} = \frac{1}{30}$ of an ampère, or a current twice as strong.

Although this explains the main difference in the amount of irritation produced. I think it is not the only factor; as the amount of irritation produced by an electric current passing through the human body is also dependent on its constancy.

Now as the resistance of the body varies frequently as much as $\frac{1}{4}$ or $\frac{1}{3}$ in three to five minutes by the soaking of the skin and the increased blood supply of the parts caused by the irritation of the electrodes, it follows that with the most constant battery we get a very inconstant current strength. If we use a battery composed of 50 Stöhrer cells, each 2 ohms resistance, and pass it through the body with 2,000 ohms, we have $\frac{70}{2000+100} = \frac{1}{30}$, if in three minutes the resistance of the body is reduced to 1,500 ohms, we have $\frac{70}{1500+100}$ we have $\frac{1}{23}$ nearly, or a variation of $\frac{1}{98}$ of an ampère in three minutes; while with 50 Daniell cells we have $\frac{50}{2000+1000} = \frac{1}{60}$ and $\frac{50}{1500+1000} = \frac{1}{50}$, or a variation of only $\frac{1}{300}$ of an ampère.

Hence the variation in one case is not $\frac{1}{3}$ as much as it is in the other.

Now as it makes no difference whether the resistance is internal or external, provided it is constant as far as the effects are concerned, it follows that we should reduce the internal resistance as much as possible in constructing a battery for medical uses, and then if we wish to increase the constancy of the current, use a rheostat; or if we want strong currents, dispense with the rheostat and soak

the skin with hot water, or hot brine, before applying the electrodes.

We see, therefore, that we should reduce the resistance of a battery for medical uses as low as possible, and this is especially important for portable batteries, as we want to get strong currents from a small battery.